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THE IMO/WMO CENTENARY CELEBRATIONS*

By D. G. HARLEY

The completion of the first 100 years of organized international collaboration in meteorology was celebrated on 7 September 1973 in the Academy of Sciences in Vienna, the place where the first International Congress was held in 1873. A gathering of several hundred, including representatives of 73 Members of WMO and 17 other international organizations, was addressed by the Federal President of the Republic of Austria, the Austrian Federal Minister for Science and Research, the representative of the United Nations Secretary-General, and the President and Secretary-General of WMO. The ceremony in the handsome 18th Century hall was enhanced by musical interludes by the Horn Quintet of the Vienna State Opera and the Nicolai Quartet of the Vienna Philharmonic Orchestra.

In the days before the official ceremony a conference reviewing the progress of the science of meteorology was held in the International Atomic Energy Agency's modern conference room near the Vienna State Opera. In the remarkable hot dry weather of that week, with daily maxima above 30°C, the air-conditioned room was most welcome. Over 200 participants from all over the world, including many well-known figures, together with a large number of meteorologists from the services of Austria and the Federal Republic of Germany, heard and discussed a series of stimulating lectures.

Dr A. Nyberg (Sweden), past President of WMO, reviewed the history of WMO and showed some well-chosen illustrations, including one of Sir Napier Shaw in top hat and morning coat showing distinguished visitors the Stevenson screen on the 1913 equivalent of the 'Air Ministry roof'. Then Mr J. S. Sawyer (United Kingdom) brilliantly discussed the development of forecasting methods, the problems of fully employing the present flood of new types of data, and the likely line of further development. Climatology's growth from the earliest collections of data to present-day statistical and mathematical modelling was discussed by Professor H. E. Landsberg (U.S.A.): his comprehensive treatment included the input from satellite measurements and the output to all manner of human activities.

Research into climatic change was stressed by Professor R. W. Stewart

* IMO = International Meteorological Organization; WMO = World Meteorological Organization.

(Canada), chairman of the Joint Organizing Committee, who reviewed the scientific aims of the Global Atmospheric Research Programme (which he did bilingually as a good Canadian). Professor P. Morel (France), as one much involved with that multi-capability tool the meteorological satellite, spoke, also bilingually, on developments in techniques of observing the atmosphere. Finally, Professor M. Neiburger (U.S.A.) reviewed developments in weather modification and the inadequate evidence on its most important aspect, rain-making.

Each session had a different discussion leader, and the sense of the discussions was aimed at the way ahead. On the last subject, however, concern was primarily with the problem of determining the extent and strength of the scientific basis for operations here and now.

A welcome interlude in the proceedings was a whole-day excursion arranged by the Austrian authorities. The very large party was taken by coach through the lovely countryside of the Vienna Woods and the Danube Valley, with several stops for sightseeing, food and wine. The day ended with an evening in Grinzing on the outskirts of Vienna, a 'Heurigen' evening with yet more food, music and wine offered by WMO.

After the weekend the participants reassembled in Geneva, the home of WMO, in the new Geneva International Conference Centre. Here, after a brief centenary ceremony, there was a two-day conference on the economic and social benefits of meteorology run on similar lines to the Vienna one.

As hors d'œuvre Mr O. Reverdin of the Swiss National Council for Research philosophized on the function of the State in respect of scientific research. Academician V. A. Bugaev (U.S.S.R.), one of the original planners of World Weather Watch, discussed its impact on economic and social development. Next day Mr S. Tewungwa of East Africa spoke of the nature and value of WMO assistance to developing countries, and was followed by Professor E. Bernard (Belgium) on the role of meteorological services in economic and social development, relatively greatest where they are weakest, in developing countries. Finally, Mr R. H. Clark (Canada) described the importance of the interface between meteorology and hydrology to water development, with a rapidly growing world demand for water, and Mr P. J. Meade (United Kingdom) described the growth from meteorology's early involvement with marine affairs up to its present close relationship with oceanography, and the future prospect that the two disciplines should increasingly be regarded as one. As in Vienna, there was discussion on each lecture, but time was short for adequate comment on such wide-ranging subjects.

The final item of the whole celebrations was an evening steamer trip with dinner and music on Lake Geneva, offered by the Swiss authorities. On a calm clear evening some hundreds of participants and their wives thoroughly enjoyed themselves on board. The air of camaraderie usual on international meteorological occasions was fully in evidence.

The whole programme was presided over by Mr M. F. Taha, President of WMO. A number of former IMO Prize winners took part, including Sir Graham Sutton, and most Members were represented by the Directors of their Meteorological Services, and, in many cases, by their Ambassadors as well. By decision of the Executive Committee, the lectures presented at both conferences will be published in the four official languages of the Organization (English, French, Russian and Spanish).

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CENTRAL ENGLAND TEMPERATURE QUINTILES AND ASSOCIATED PRESSURE ANOMALIES ON A MONTHLY TIME-SCALE

By R. MURRAY and J. D. LANKESTER

Summary. The climatological association between temperature quintiles in central England and pressure anomaly patterns over the northern hemisphere on the monthly time-scale are presented. For the two extreme quintiles the circulation patterns are generally opposite in type. The characteristic seasonal changes of pressure anomaly patterns associated with temperature quintiles are discussed.

Introduction. Quintiles of monthly mean temperature in central England (see Manley[1] and Murray[2]) are commonly employed in long-range weather forecasting in the Meteorological Office. Maps which show the field distribution of monthly mean pressure anomaly over most of the northern hemisphere typically associated with each temperature quintile for each month of the year are available. These maps form the basis of this descriptive account of the main features of the anomalous atmospheric circulations which are climatologically characteristic of the temperature quintiles throughout the year. A particular temperature in an individual month can, of course, arise from a variety of circulation types. However, there tends to be a typical circulation associated with each of the different temperature quintiles, especially for the extreme quintiles 1 and 5, and the climatology of these mean circulations is of some interest.

In the present note the monthly mean pressure averages refer to the period 1873–1968, and the quintile boundaries of monthly mean temperature in central England are as given by Murray.[2]

Mid-season monthly pressure anomaly patterns. Skeleton maps of composite monthly mean pressure anomaly patterns for temperature quintiles 1 (= very cold) and 5 (= very warm) are depicted in Figures 1–4, which refer to January, April, July and October respectively.

The striking feature of Figure 1(a) is the very large-scale blocking signified by the positive anomaly centre (PAC) greater than 10 mb over Iceland and the negative anomaly centre (NAC) less than minus 4 mb over Spain typically associated with very cold weather (quintile 1) in central England in January. Very cold weather in central England in the other mid-season months is also typically associated with blocking over the north-east Atlantic, but the high-latitude PAC weakens to a minimum in July (Figure 3(a)) and the NAC which was over Spain in January (Figure 1(a)) weakens a little and drifts northwards to southern Sweden in July. For the quintile 1 case the very strong easterly anomaly of flow over Britain (associated with above-average pressure) in January backs to north-west to north (with below-average pressure) in July.

In the quintile 2 (cold) cases the main PACs and NACs are generally weaker than the corresponding anomaly centres in the quintile 1 classes in all mid-season months; this indicates the greater variability of pattern which contributes to quintile 2, compared with the variability of pattern which contributes to quintile 1.

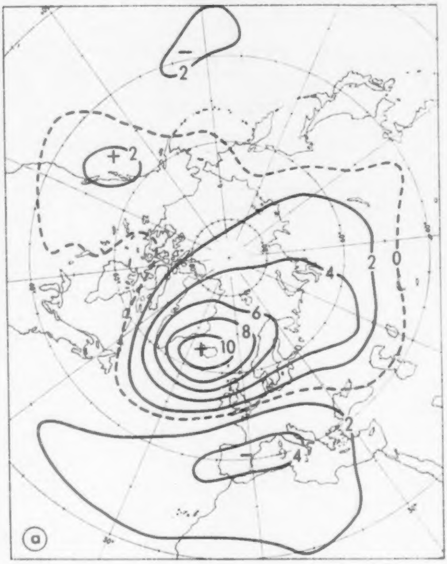


FIGURE 1(a)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 1 JANUARYS IN CENTRAL ENGLAND (IN MILLIBARS)

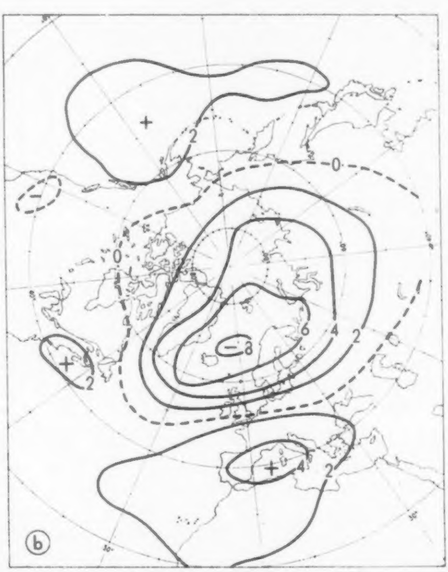


FIGURE 1(b)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 5 JANUARYS IN CENTRAL ENGLAND (IN MILLIBARS)

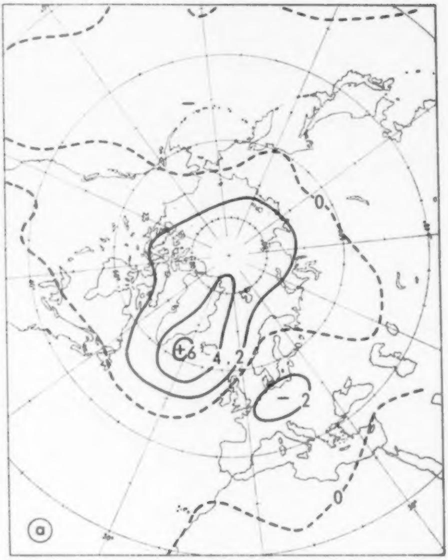


FIGURE 2(a)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 1 APRILS IN CENTRAL ENGLAND (IN MILLIBARS)

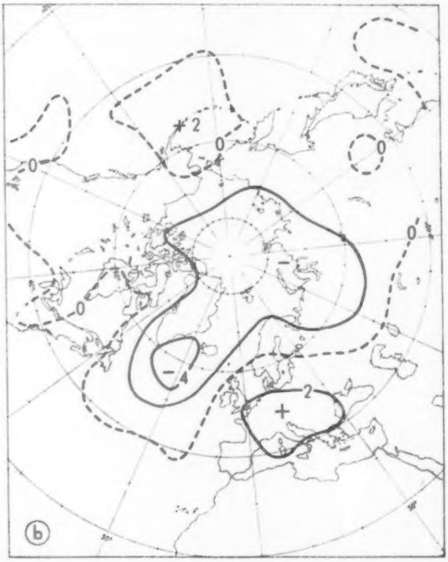


FIGURE 2(b)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 5 APRILS IN CENTRAL ENGLAND (IN MILLIBARS)

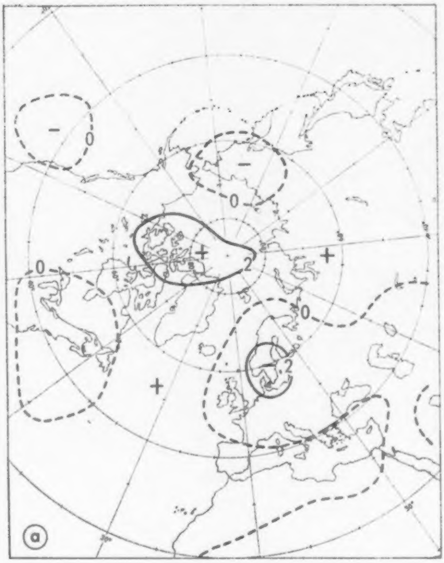


FIGURE 3(a)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 1 JULYS IN CENTRAL ENGLAND (IN MILLIBARS)

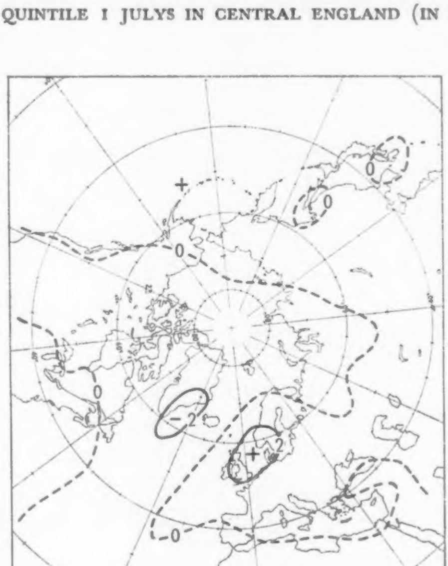


FIGURE 3(b)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 5 JULYS IN CENTRAL ENGLAND (IN MILLIBARS)

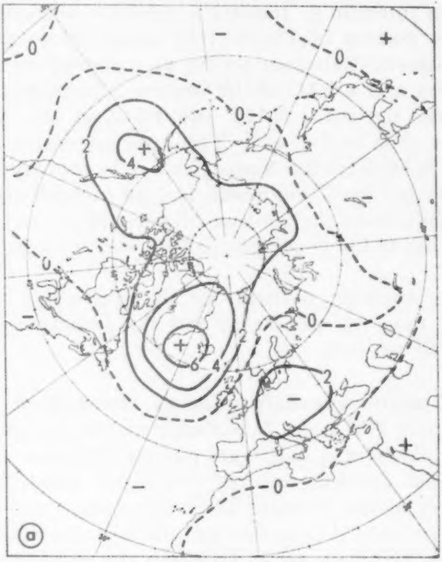


FIGURE 4(a)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 1 OCTOBERS IN CENTRAL ENGLAND (IN MILLIBARS)

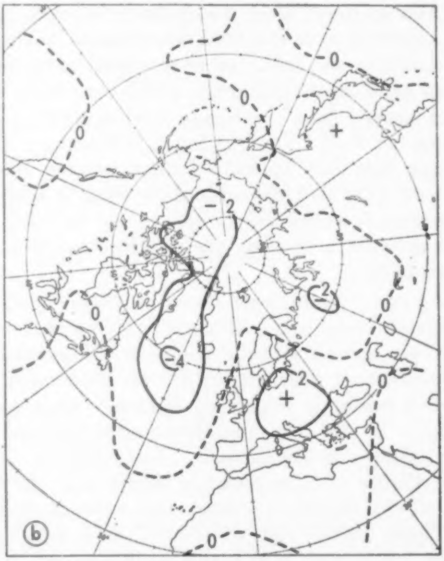


FIGURE 4(b)—COMPOSITE MONTHLY MEAN PRESSURE ANOMALY MAP IN SKELETON FORM FOR QUINTILE 5 OCTOBERS IN CENTRAL ENGLAND (IN MILLIBARS)

The very warm (quintile 5) January is typically associated with the mean pressure anomaly pattern of Figure 1(b) which shows a very progressive pattern in the Atlantic–European sector, as suggested by a strong NAC in the Norwegian Sea and a PAC in the western Mediterranean. In the other mid-season months the main NACs and PACs in the Atlantic–European sector are weaker than in January. The most interesting feature, however, is the shift of the NAC from the Norwegian Sea in January to near south-east Greenland in July and to off south-west Iceland in April and October, whilst the main PAC shifts from the western Mediterranean in January to central Europe in April and to the North Sea in July, then returns to central Europe in October.

The composite anomaly patterns for the quintile 4 (warm) class are generally weaker than for quintile 5, and this indicates greater variability of pattern in the former case.

Locations of main anomaly centres throughout the year. The positions of the main PACs and NACs each month typically associated with temperature quintiles 1, 2, 4 and 5 are plotted in Figure 5(a)–(d). In these diagrams the main anomaly centres which are necessary to depict the significant features of the pressure anomaly patterns are indicated. PACs are shown as crosses and NACs as dots and the adjacent figures give the month (1 = January, 2 = February, etc.). In winter the absolute values of anomaly centres are much stronger than in summer, as may be seen by comparing Figure 1 with Figure 3.

A cursory examination of Figure 5(a) shows that the North Atlantic PACs for all quintile 1 months except June are clustered near Iceland, with the corresponding NACs scattered over the Atlantic between 35° and 45°N and over Europe but clustered near southern Scandinavia in the summer months. There is also a tendency for PACs to be grouped over the Siberian Arctic in the summer and early autumn, but the NACs are widely scattered over the North Pacific and eastern Asia. In Figure 5(b) (quintile 2) the PACs for all months except June are in the North Atlantic between 45° and 65°N with the NACs over Europe and the central Mediterranean. Whereas it may be inferred from Figure 5(a) that the quintile 1 months tend to be associated with east or north-east anomalies of flow over Britain, it is clear from Figure 5(b) that quintile 2 months are usually associated with north-west or north anomalies of flow.

In the quintile 5 (very warm) case shown in Figure 5(d) there is a cluster of NACs near Iceland (compared with the PACs in a similar region in Figure 5(a)) and PACs are clustered near southern Scandinavia from May to September but mostly in or near the central Mediterranean in other months. In this case there is evidently a marked tendency for a south-east anomaly of flow over Britain in the five summer months and mostly a south-west anomaly of flow at other times of the year. Away from the Atlantic–European sector there is, in Figure 5(d), a group of NACs near the Kara Sea (to the east of Novaya Zemlya), mostly in summer and autumn, and a preponderance of PACs in the North Pacific east of 180°W. It is also noteworthy in this diagram that the PACs and NACs are often located in broadly similar geographical areas to the NACs and PACs respectively in Figure 5(a) in corresponding months; in other words Figure 5(d) is rather like Figure 5(a)

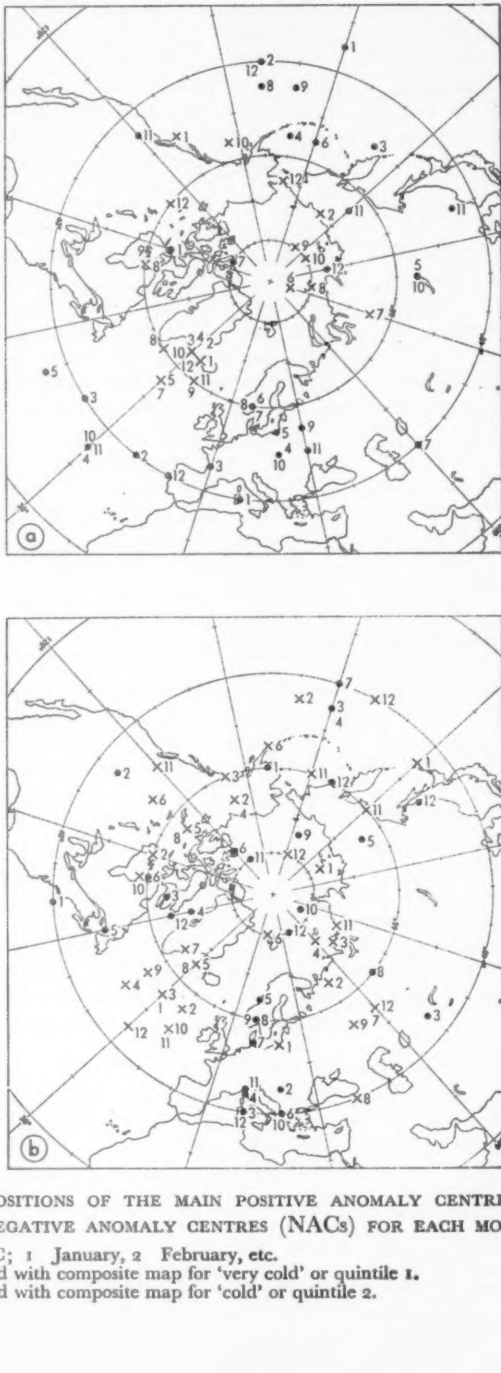
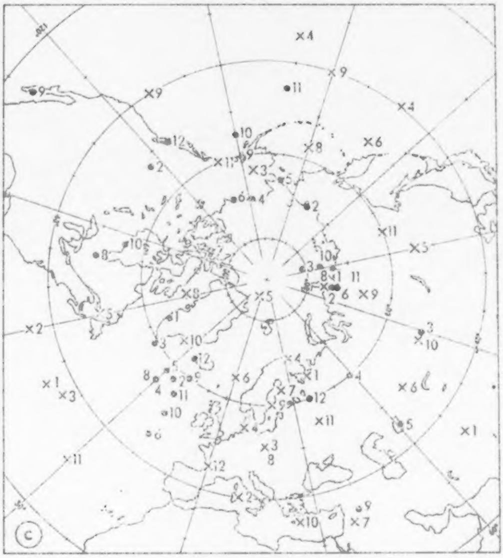


FIGURE 5—POSITIONS OF THE MAIN POSITIVE ANOMALY CENTRES (PACs) AND NEGATIVE ANOMALY CENTRES (NACs) FOR EACH MONTH

× PAC; · NAC; 1 January, 2 February, etc.
(a) associated with composite map for 'very cold' or quintile 1.
(b) associated with composite map for 'cold' or quintile 2.



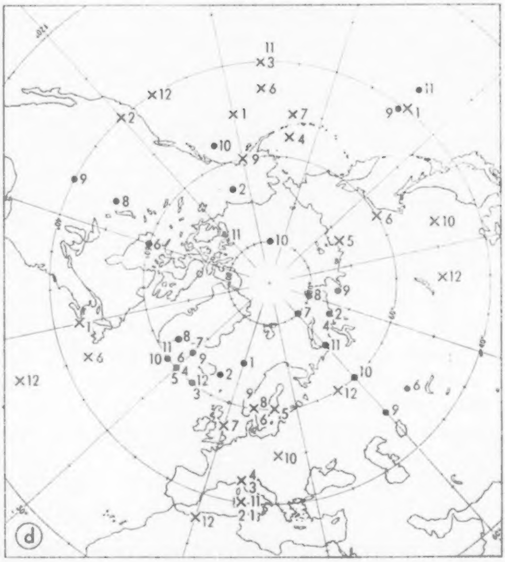


FIGURE 5—*continued*

(c) associated with composite map for 'warm' or quintile 4.
(d) associated with composite map for 'very warm' or quintile 5.

with the signs of the anomaly centres interchanged. In the quintile 4 or warm case, shown in Figure 5(c), there are clearly rough similarities in the positions of the PACs and NACs compared with the distribution of the anomaly centres shown in Figure 5(d) (quintile 5). However, it is noticeable in Figure 5(c) that the NACs in the Atlantic are not so closely clustered together as in Figure 5(d). It is also interesting to observe that Figure 5(c) (quintile 4) resembles Figure 5(b) (quintile 2) with the signs of the anomaly centres reversed.

Seasonal variation of monthly pressure anomaly. In Figure 6(a) is shown the monthly mean pressure along the Greenwich meridian during the year, whilst the variations of monthly mean pressure anomaly associated with the composite anomaly maps for the extreme temperature quintiles (quintiles 1 and 5) are shown in Figures 6(b) and 6(c). It is noteworthy that the high-latitude positive anomaly (PA) in Figure 6(b) — the very cold case — is greatest near 70°N in midwinter and at a minimum near 80°N in late summer, whilst the negative anomaly (NA) in low latitudes also appears to move to higher latitudes by the end of the summer; in the latitudes of the British Isles there is clearly a strong easterly anomaly of flow in winter associated with marked anticyclonic blocking, but in the summer the low temperature is associated with below-average pressure (i.e. with cyclonic weather types). Figure 6(c) — the very warm case — shows a pattern which is like that in Figure 6(b) with the signs of the anomalies reversed; in particular over Britain there is a westerly anomaly of flow in winter and above-average pressure (i.e. anticyclonic weather types) in summer.

Figure 7(a) gives the monthly mean pressure along latitude 55°N during the year. In Figures 7(b) and 7(c) are shown the seasonal variations of monthly mean pressure anomaly, associated with the composite anomaly maps for the extreme temperature quintiles, along 55°N. Once again it is evident that Figure 7(b) (very cold case) is like Figure 7(c) (very warm case) with the signs of the anomalies reversed. In Figure 7(b) the main positive pressure anomalies are in the central Atlantic each month, with the smallest anomalies in the summer; negative anomalies are generally east of 10°W over the European sector except in January and February. Clearly very cold weather in central England is generally associated with a northerly component of anomaly flow in most months but particularly in spring and autumn. In contrast, in Figure 7(c) below-average pressure generally occurs in the Atlantic and above-average pressure over Europe, with a southerly component of anomaly flow over or near Britain.

Finally, in Figure 8 the pressure anomaly and direction of the anomaly flow at the grid point 55°N 00° for each quintile of temperature throughout the year are conveniently tabulated. The seasonal variation of the local circulations near central Britain, typically associated with the different quintile classes, can be seen at a glance and related to the large-scale circulation described in the other figures. It must of course be remembered, as mentioned in the Introduction, that a specific month may have a temperature/circulation association which is quite untypical of the climatological relationship, particularly with quintiles 2, 3 and 4.

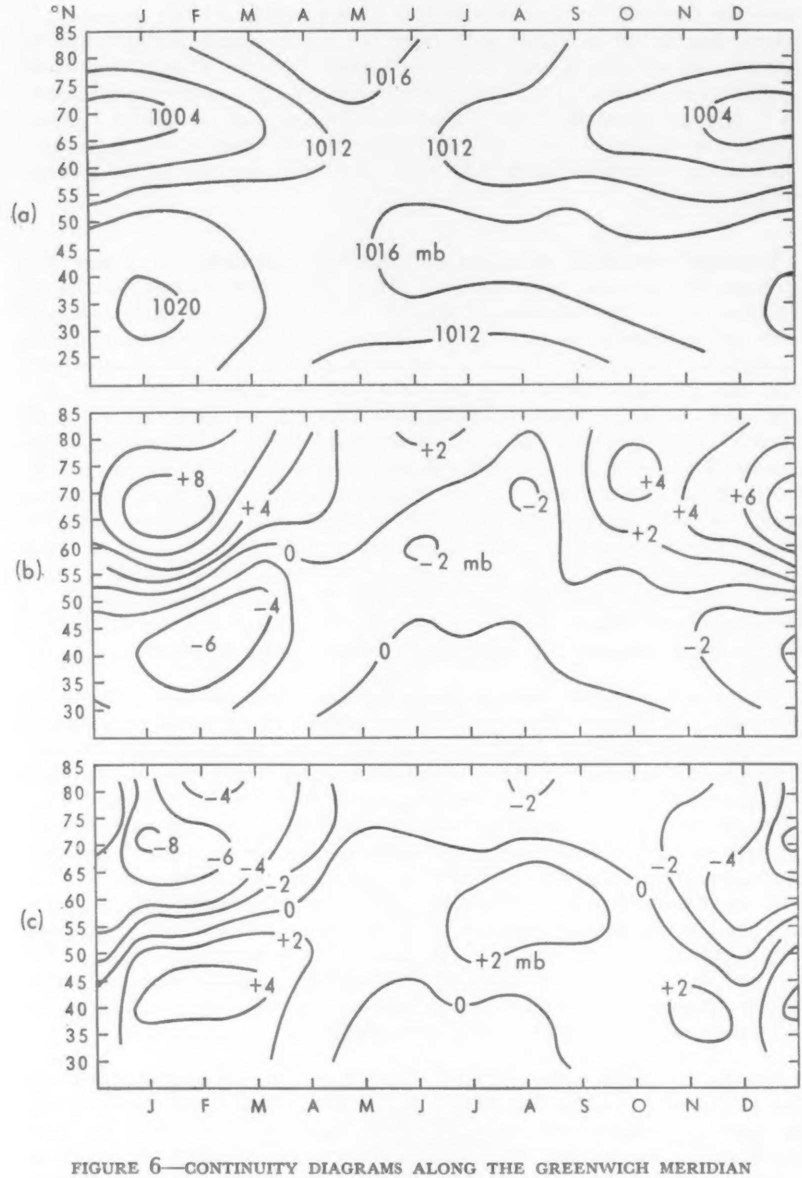


FIGURE 6—CONTINUITY DIAGRAMS ALONG THE GREENWICH MERIDIAN

(a) monthly mean pressure (1873–1968); (b) monthly mean pressure anomaly associated with composite map for quintile 1 temperatures in central England; (c) monthly mean pressure anomaly associated with composite map for quintile 5 temperatures in central England.

Note. For convenience in presentation isobaric isopleths are drawn smoothly from the discrete monthly data.

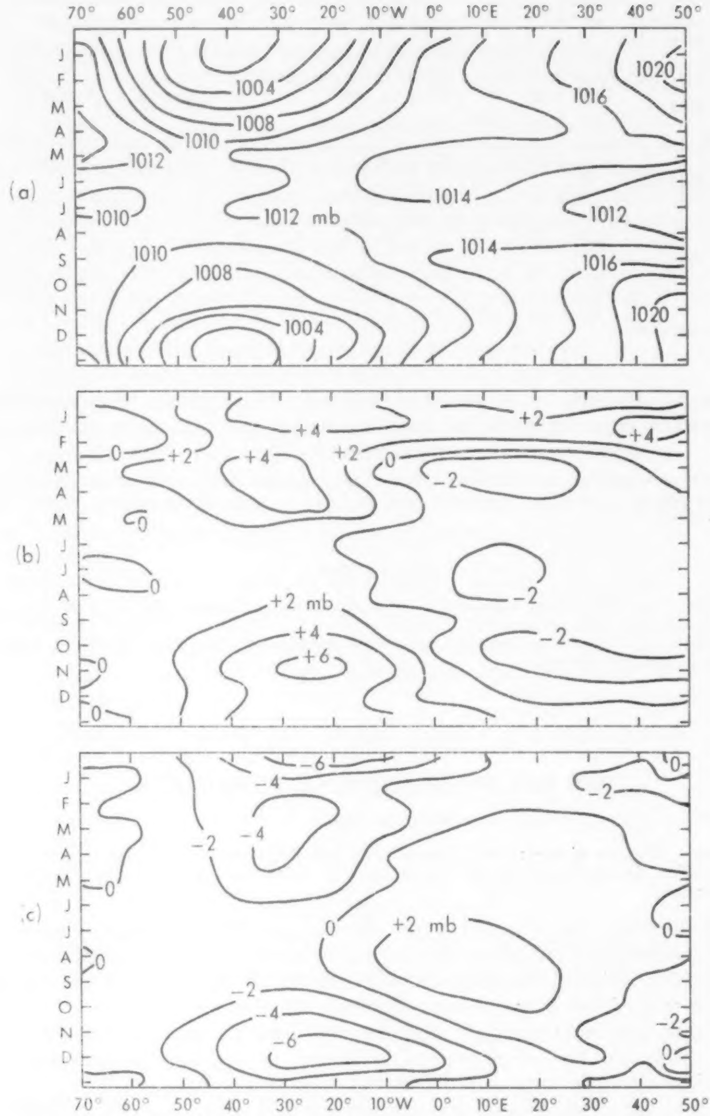


FIGURE 7—CONTINUITY DIAGRAMS ALONG LATITUDE 55°N

(a) monthly mean pressure (1873–1968); (b) monthly mean pressure anomaly associated with composite map for quintile 1 temperatures in central England; (c) monthly mean pressure anomaly associated with composite map for quintile 5 temperatures in central England. See note in caption to Figure 6.

	J	F	M	A	M	J	J	A	S	O	N	D
1 Very cold	← +3·3	↖ +1·9	↙ −2·7	↙ −0·6	↓ −0·5	↘ −1·7	↓ 1·6	↘ −1·8	↙ +0·2	↙ −0·4	↓ +1·6	↙ +1·0
2 Cold	⊕ +1·1	↙ −0·2	↙ +0·5	← −0·2	↘ −0·4	← −0·4	⊙ −1·4	⊙ −1·5	↘ −1·5	↓ +1·5	• +0·1	↙ +0·9
3 Average	↓ −1·0	⊕ +2·2	↙ +1·3	⊙ −0·9	↗ −0·2	→ +0·8	↑ −0·8	→ −0·3	→ −1·2	↗ −0·5	↙ +1·3	↗ +0·3
4 Warm	↗ −1·5	↗ −2·6	↗ +1·0	↗ +0·4	↑ −0·1	↖ +0·4	↖ +1·3	↑ +0·3	↖ +0·1	↑ −1·4	↗ −1·5	→ +1·3
5 Very warm	→ −1·4	↗ −1·6	↗ +0·6	↗ +1·2	↖ +1·3	↖ +1·1	⊕ +2·8	↖ +3·3	↖ +2·6	↗ +0·7	↗ −1·4	↑ −4·4

FIGURE 8—MONTHLY MEAN PRESSURE ANOMALY IN MILLIBARS AND DIRECTION OF ANOMALY FLOW AT 55°N 00° FROM COMPOSITE MAP FOR EACH QUINTILE OF MONTHLY MEAN TEMPERATURE IN CENTRAL ENGLAND

Ill-defined directions are indicated as a dot when associated with a col pattern, and as an encircled dot or cross when associated with cyclonic or anticyclonic patterns respectively near 55°N 00°.

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1. MANLEY, G.; The mean temperature of central England 1698–1952. *Q J R Met Soc, London*, **79**, 1953, pp. 242–261.
2. MURRAY, R.; A note on central England temperatures in quintiles. *Met Mag, London*, **99**, 1970, pp. 292–294.

551.509.313

THE USE OF NUMERICAL FORECASTS

By T. H. KIRK

Summary. The use of numerical forecasts is illustrated by procedures at the Central Forecasting Office, Bracknell and an attempt is made to define the legitimate role of subjective interpretation.

Introduction. In a recent paper Brown and Fawcett[1] have illustrated both numerical and subjective procedures in use at the National Meteorological Center (NMC), Washington, with particular emphasis on the 'man-machine mix'. They stressed three important conclusions :

(a) that the meteorologist produces the best forecast by careful and systematic use of numerical guidance as opposed to independent forecasting in competition with the computer product;

(b) that the meteorologist's average forecast skill improves in direct proportion to the improvement in numerical forecast guidance that he uses; and

(c) that the better the numerical prognosis, the more difficult it is to improve manually with any degree of success.

This note also deals with aspects of the use of numerical products and the extent to which these should be accepted at face value or as guidance

material. The content is based on experience at the Central Forecasting Office (CFO), Bracknell and on the procedures in use there, but some attempt is made to view the problem in terms of general forecasting.

The subject is considerably simplified if the essential role of the forecaster is correctly appreciated.

The function of the forecaster. The forecaster is concerned in general with the interpretation and forecasting of events over the whole gamut of weather processes. His field of activity extends over the vast number of observations, both subjective and instrumental, available at synoptic hours, together with an increasing variety of asynoptic observations from aircraft and satellites. For the efficient handling of such a quantity of data it has become necessary to use methods of data processing, analysis and forecasting based on the computer, and these will improve progressively both in scope and in accuracy. The forecaster's essential role is the exercise of discrimination or judgement within the context of the available information and the needs of his customers. In the 'man–machine mix', the advantages of the computer as a calculator and data processer are combined with the human ability to exercise judgement. If some justification of this position is required, it may be sufficient to point out the severe limitations of the human being as a calculator and data processer; on the other hand, only the human brain can exercise judgement in the complex situations with which the forecaster is concerned.

To solve his particular problem the forecaster may have available :

Numerical products.

(a) A variety of computer products based on different models, e.g. barotropic or baroclinic, filtered or primitive-equation, 6-level or 10-level, dry or moist.

(b) Computer products on different scales, e.g. octagon model (large-scale), rectangle model (fine-mesh).

(c) Products from different World Meteorological Centres, Regional Meteorological Centres or National Meteorological Centres, obtained through World Weather Watch.

Additional observations.

(a) Local observations, e.g. for local forecasting.

(b) Special observations, e.g. sferics, radar, for mesoscale forecasting.

(c) Observations at a time later than that on which the computer products are based.

(d) Satellite observations, e.g. automatic picture transmission (APT) photographs.

Special knowledge. Additionally, for any particular model, the forecaster may know :

(a) The data deficiencies of the model, i.e. whether the analysis is a good one or is deficient in some essential feature.

(b) The model deficiencies, i.e. the extent to which significant physical processes are either not incorporated or are inadequately represented in the model.

(c) The existence of systematic mathematical inaccuracies, e.g., truncation errors.

(d) The performance as determined by evaluation studies; in particular, the existence of systematic errors.

(e) The existence of geographical or seasonal errors.

Theoretical and empirical knowledge. The forecaster has a background of theoretical and empirical knowledge much of which is not incorporated in the forecast models and which can be used in particular circumstances. He is also acutely aware of the different scales of meteorological events and of the limitations of models particularly in relation to most features of weather as distinct from the analytical parameters associated with the large-scale circulation.

The relevance of much of this information depends on the particular problem under examination, as does the forecaster's attitude. The extent to which judgement is exercised varies with the particular need. The fundamental principle is that objective methods should be used to the fullest extent compatible with the requirement so that judgement can be more effectively exercised at a higher level. It is unnecessary for expert judgement to be employed in circumstances where routine objective techniques can be used to provide an adequate service. Forecast verification has an obvious part to play in furthering this approach.

Procedures at CFO, Bracknell. Procedures at CFO, Bracknell, may be used to illustrate some features of the above remarks and to emphasize the complex interplay of subjective and objective aspects in forecasting.

Intervention. The term 'intervention', some aspects of which are described as 'bogusing', is used to describe the process whereby the forecaster modifies the data available to a forecast model. It includes :

(a) The early scrutiny of selected data and the rejection or correction of observations. This is additional to the quality-control procedures used in the computer.

(b) Monitoring the objective analysis and taking action to correct the background field which provides the basis for the next analysis. Intervention incorporates the subjective influence of the forecaster at an early stage in the forecast process and at present is an essential element in operational forecasting.

Subjective 24-hour surface prognoses. Numerical forecasts (for 1000 mb, 500 mb, 300 mb, 1000–500-mb thickness and of thermal vorticity), are used by the Senior Forecaster in the preparation of his 24-hour surface prognoses. On two occasions per day, in the preparation of forecasts for 06 GMT and 18 GMT, the numerical guidance constitutes a 30-hour forecast, whereas numerical guidance for the 00 GMT and 12 GMT forecasts is for 36 hours in advance. The forecaster modifies the 1000-mb numerical forecast on the following grounds :

(a) That he has some knowledge of the limitations of the analysis on which the forecast was based and of the forecast model itself.

(b) That he has later data.

(c) That he wishes to incorporate significant features of a smaller scale than can be expressed by the forecast model, e.g. fronts, polar lows.

As a result of the enforced timing of operational requirements in relation to the twice-daily issues of computer forecasts, the guidance for a 24-hour forecast represents a 30-hour or 36-hour forecast from the computer. Direct comparison of the performance of 24-hour subjective and numerical forecasts is therefore neither realistic nor significant for the operational need.

Medium-range forecasts. Forecasts for two and three days ahead are produced daily in which numerical forecasts are used as a basis. The forecasts used are CFO numerical prognoses at 1000 mb and 500 mb for 48 hours and 72 hours and the United States NMC prognoses at 500 mb for 48 hours and 72 hours. German prognoses are also occasionally consulted.

Subjective prognoses for 48 hours and 72 hours are produced by modifying the computer products where necessary. This modification has as its basis knowledge of :

(a) Model deficiences.

  (1) The systematic error, characteristic of numerical forecasts, in the eastwards progression of troughs and ridges, i.e. phase lag.

  (2) The lag in the change of amplitude of wave features.

  (3) The inadequate representation of cyclogenesis.

(b) Analysis deficiencies, where known, e.g. of the CFO model.

(c) Later data.

The forecaster critically compares the corresponding prognoses of the different numerical models available to him in the light of :

(a) Continuity of events in the real atmosphere.

(b) Continuity in the performance of the different models.

(c) Known characteristics.

His final subjective version may be based on a particular numerical model, suitably modified, or may be a compromise between different solutions. Evaluation has shown that the subjectively modified forecasts are an improvement on the numerical forecasts from any particular model. The fact that the subjective element is of real significance has been shown by a decision to use a minimum number of selected forecasters on this task. A marked improvement in performance was achieved by the implementation of this decision.

Aviation forecasts. Forecast information for route planning at all upper levels is issued directly from the numerical model and is unmodified. Evaluation has shown that no systematic improvement can be achieved in practice by subjective modification.

For briefing aircrew, however, forecast charts at 200 mb, 250 mb, 300 mb, 500 mb, and of tropopause and maximum wind are prepared by subjectively modifying numerical forecasts. The argument for this procedure rests on

the need for providing more-precise information on jet streams and detailed structure at the tropopause. The advantages are marginal and it is a matter of opinion whether they justify the additional effort involved.

Here, then, is an area where subjective modification, although perhaps justifiable for some purposes at present, will probably be unprofitable in future. This illustrates the necessity for adopting a pragmatic attitude towards the satisfaction of forecast requirements.

General forecast practice. The forecaster at an outstation who has to use numerical products is in general in a much weaker position to judge their adequacy than the forecaster at CFO. The following notes illustrate possibilities :

Manual monitoring of objective analysis. It cannot be assumed that the objective analysis received from some large forecast centre incorporates all the data available, and the forecaster should examine it in relation to the data, particularly late data in the area with which he is concerned. The basic object is to sharpen the analysis by examining known or suspected areas of uncertainty. The checks should include :

(a) Positions and depths of low-pressure centres.

(b) Positions and sharpness of troughs and ridges.

(c) Identification of zones of steep gradients, e.g. jet streams on upper-level charts.

(d) Absolute values of individual isopleths.

The obvious method of checking consists in the plotting of significant observations on a copy of the analysis chart. Amendments can then be made as necessary.

Manual monitoring of numerical forecasts. Numerical prognostic charts are available to most forecasters and are a useful and necessary basis for practical forecasting. They have, however, certain inherent deficiencies which make them less accurate, and hence less useful, than they could otherwise be. These deficiencies may arise :

(a) From an analysis which is inadequate for its purpose, in general owing to insufficient or badly distributed data at the time of preparation.

(b) From the inability of the model accurately to represent all the different types of development which can occur in the real atmosphere.

(c) From the inevitable mathematical inaccuracies in calculation, e.g. truncation errors.

These considerations provide the justification for attempting to modify and improve numerical forecasts. The modified product may or may not be more accurate in general statistical terms than the original numerical forecast because manual modification inevitably introduces its own inconsistencies, but the ultimate justification is that it can be more suited to its particular purpose. For normal flight-planning purposes, the automated upper-air chart is adequate; as a briefing aid for the information of pilots more detail may be required and manual modification can be used to emphasize the positions and strengths of jet streams and the details of the wind and temperature fields at flight levels.

Surface numerical forecast charts require routine modification to show small-scale synoptic detail and frontal structure significant for weather events. Whether considered in relation to upper-air charts or to surface charts, the forecaster's function cannot be visualized solely as one of error removal. There is of course this aspect, and it is most important; additionally, however, there is the necessity of adding small-scale detail of real practical significance, particularly as concerns the surface forecast. The techniques for doing this are the traditional subjective forecasting methods.

The following remarks relate to elements of bias and error which are sufficiently systematic to be noticed by forecasters in day-to-day contact with numerical forecasting products :

(a) Over data-sparse areas in general, and ocean areas in particular, satisfactory analysis depends disproportionately on the reception of a few critical observations, e.g. those from ocean weather ships. If one or more of these is missing (e.g. late or rejected) then the analysis, and also the subsequent forecasts, may be appreciably in error. The forecaster may be in possession of these observations at the time of reception of the forecast and will be in a position to judge to what extent the forecast would have been different, had the missing observations been available at the time of analysis.

Even when critical observations are available, it may happen that in a rapidly developing situation the computer will not react realistically and sufficiently quickly to the new observations on account of the inhibiting effect of the background field. The discerning forecaster will be aware of this possibility and will be prepared to face the necessity of making appropriate adjustments to the forecasts.

The problem of 'updating' is also relevant. Numerical charts are produced on a twice-daily cycle whereas most forecast requirements are based on six-hourly intervals. Intermediate surface observations are always available and they occasionally indicate the beginnings of rapid changes which have not adequately been taken into account in the computer forecasts.

(b) Models in use in numerical forecasting are of different degrees of sophistication in that they attempt to take account of different physical processes to a lesser or greater extent. If some physical process is not included in the model, then the numerical forecast is necessarily deficient in this respect. Of more importance to the forecaster is the fact that nominal inclusion of some physical process in the model is no guarantee that this process will be handled effectively or that the results will be at all realistic. Forecasters should know the details and basic assumptions of the different models in current operational use, so that they are not led to expect too much in any particular circumstances. The limitations of most numerical models are in general carefully stated before they are introduced into operational practice. Once in use, these limitations are often conveniently forgotten, and the models tend to be used beyond the limits for which they were designed.

(c) As mentioned earlier, most numerical models are subject to phase error, are somewhat inadequate in their treatment of rapid changes of wave amplitude, and are unable to handle small-scale cyclogenesis at all realistically.

There is therefore plenty of scope for the manual refinement of numerical products, but it is worth emphasizing that manual methods of adjustment should be based on recognized statistical and synoptic methods of assessment.

The forecaster's normal background of experience is a poor substitute for objective tests, and the amendment of numerical prognoses cannot be justified on this basis alone. Objective knowledge of the behaviour of each model in an operational context must be obtained in a systematic way. Vague subjective impressions are not a sufficient basis for action.

Conclusion. Throughout this account, a situation has been envisaged in which the forecaster has access to sources of information and theory additional to the available computer products. It is this additional information and knowledge which provide the basis and the justification for his attempts to modify any numerical forecasts. In practice, only he can decide the extent to which he is justified; for certain purposes and in certain situations he may know from evaluation studies that the numerical product already satisfies the operational need and hence that modification would be unnecessary. In other instances it may be known that subjective modification, although inherently desirable, is ineffective in practice. Some requirements, particularly those concerned with detailed distributions of weather elements in space and time, may demand that the forecaster use the numerical products as guidance only, basing his final forecasts partly on the automated products and partly on additional data, empirical knowledge and theoretical considerations extraneous to them. It must be remembered that most models are based on relatively few analytical parameters and that a vast amount of data is not utilized. This extra-model information, although perhaps of little relevance to large-scale atmospheric circulation, may be vital for a local problem.

In considering the conclusions of Brown and Fawcett, cited above, the meteorologist produces a better forecast by using the automated products as a basis because they are derived objectively, by known mathematical procedures, from well-established physical principles. Within the limitations of the physical model there is no different method capable of providing a better basis. Numerical models, like all other physical models, must be tested and evaluated. Known limitations provide a means of improvement either by subjective modification or, better still, by improvements to the model itself. Improvements to the numerical model entail a diminishing possibility for further subjective criticism. The area of subjective modification progressively diminishes, but this does not render the forecaster any the less necessary. Forecast periods are being extended in time and there will always be demands at the margin of the capability of present models offering scope for subjective criticism and forecast modification. The development of mesoscale models is only in its infancy and subjective interpretation and forecast modification have an even more important role to play in this field. Interpretation, on which any forecast modification must be based, implies the application of theoretical knowledge and information not intrinsic to the model under consideration. With the ever-present tyranny of detail it is difficult to envisage either a time or a situation when the forecaster will not be able to make valuable contributions to at least some forecast products.

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LARGE CHANGES IN WIND PATTERNS AT SEA

By WAYNE V. BURT, TIMOTHY CUMMINGS and CLAYTON A. PAULSON
(School of Oceanography, Oregon State University, Corvallis, Oregon, U.S.A.)

Summary. Diurnal variations in the wind over the North Atlantic were observed in September 1972. There were unexpectedly large changes in the character of these variations over relatively short distances.

Introduction. Burt *et alii*[1,2] found great regularity in the diurnal cycles of wind velocity in two studies of wind velocity over the ocean near the coast. Both studies were made from records for periods somewhat shorter than two weeks during the season of the year when the wind was relatively steady in direction. The areas studied were areas of strong oceanic upwelling, one off the coast of Peru and the other off the coast of Oregon.

An opportunity arose to see if the same sort of variability existed over the open ocean in mid latitudes during Operation JASIN (Joint Air Sea Interaction) 1972, which was sponsored by the Royal Society and took place in the North Atlantic west of Ireland near Ocean Weather Station J (52° 30′N, 20° 0′W) during the month of September 1972.

Method. Data were taken from cup anemometers mounted on four buoys located as shown in Figure 1. Wind speed and direction were recorded at 10-minute intervals for the same 12·7 days on all four buoys. In Burt *et alii*[1,2] the co-ordinate systems were defined by the coastline, and the variability was studied of both the long-shore and onshore components of the surface wind. For the JASIN wind study, in the absence of a coastline, the u component was taken as positive to the east, and the v component positive to the north. Hourly averages of u and v were taken for each hour of the day during the study period. Values for each hour of the day were then averaged for the study period, this process resulting in four sets of 24 pairs of values of u and v, one set for each buoy. A sinusoidal curve with a 24-hour period was fitted by means of a least-squares technique to each of the data sets. Then for each hour of the day pairs of u and v fitted values were plotted with u as the x-axis and v as the y-axis, which resulted in an ellipse for each set of 24 plotted points as shown in Figure 2.

The orientations of the major axes of the ellipses are similar for all four buoys with the eccentricity larger for buoys B2 and A than for buoys B1 and D2. The mean wind vector for buoy B1 is to the north-west, while that for buoy D2 is practically zero. The mean wind vector for the other two buoys is to the south-east, but the magnitude of the vector for buoy A is larger than that for buoy B2. There appears to be a systematic variation in the mean wind direction, magnitude, and the eccentricity of the wind ellipse on a roughly north-east to south-west line.

Discussion. During the period of this study most of the area covered by the JASIN study was dominated by an intense high-pressure system. However, several low-pressure systems passed through areas close to the JASIN area and had some effects on the weather within it. Wind speeds were low and a flat pressure gradient existed over the JASIN area for most of the time during the study.

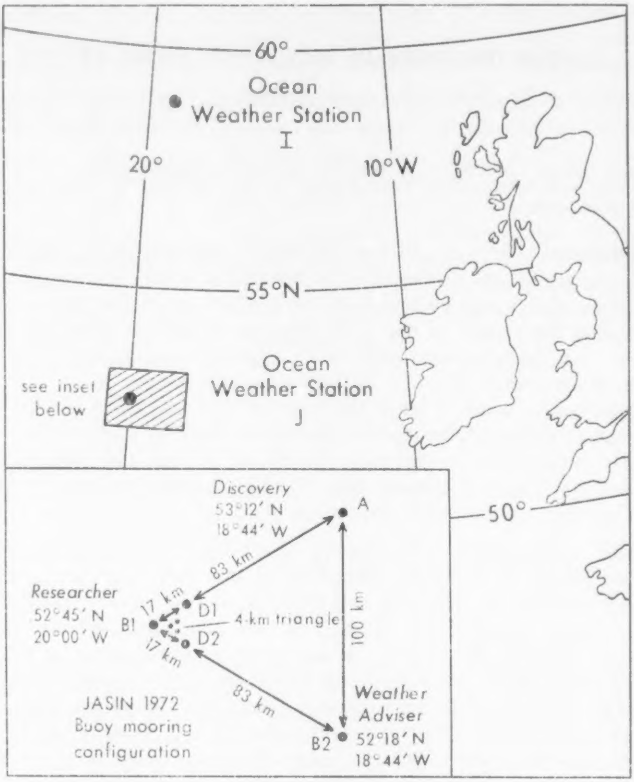

FIGURE 1—THE RELATIVE POSITIONS OF THE METEOROLOGICAL BUOYS AND PARTICIPATING SHIPS DURING JASIN 1972

Under these circumstances one would expect that the wind would vary considerably over the area in speed and direction at any given time. However, it was quite a surprise to the authors to find that the mean diurnal variation in speed and direction, when averaged over an almost two-week period, could vary so much over such short distances.

Acknowledgements. We wish to thank Professor Henry Charnock, Director of the United Kingdom Institute of Oceanographic Sciences, for inviting us to participate in JASIN 1972, and Dr Raymond T. Pollard, Co-ordinator for JASIN 1972, for assistance and encouragement in many ways.

This research was supported by the Global Atmospheric Research programme of the National Science Foundation under Grant GA 28004 and by the North Atlantic Treaty Organization under Grant #3 (SA-6-5-02(3) 39 TK).

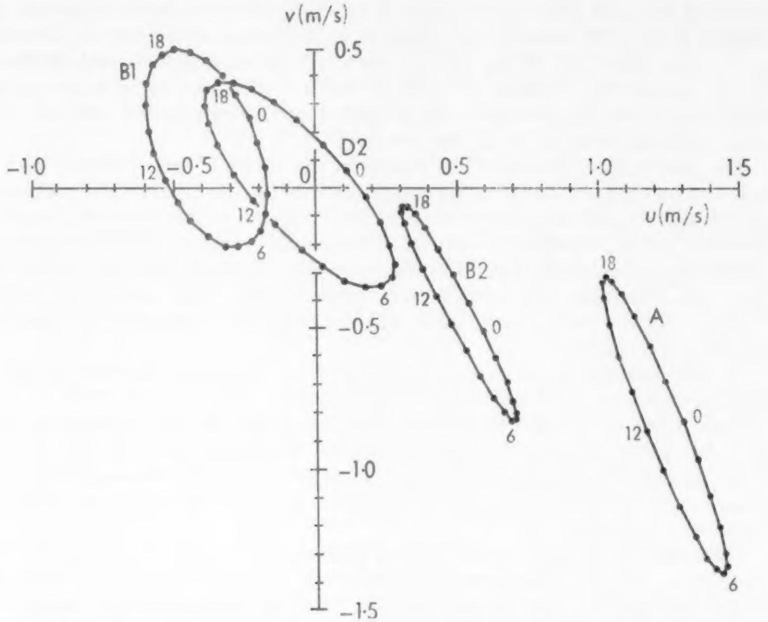

FIGURE 2—ELLIPSES CONSTRUCTED FROM THE MEAN HOURLY WIND VECTORS AS MEASURED FROM FOUR METEOROLOGICAL BUOYS DURING A 12·7-DAY PERIOD

Times are shown in GMT.

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REVIEWS

Understanding our atmospheric environment, by Morris Neiburger, James G. Edinger and William D. Bonner. 260 mm × 175 mm, pp. xi + 293, *illus.*, W. H. Freeman and Company Limited, 58 Kings Road, Reading, England RG1 3AA, 1973. Price: £4·70.

Weather is and always has been a topic of vital interest to man and in this present era, when there is increasing interest in our environment it is more necessary than ever to keep the non-specialist informed.

This American book is intended for non-meteorologists, for students majoring in subjects other than a physical science, and has been written as basic instruction for a course covering about one university term. Naturally, as

the authors point out, meteorology is too extensive a subject to permit all aspects to be well covered in a book of such limited scope but nevertheless they claim, justifiably in my opinion, to touch on most aspects and the book should enable the students to reach a better understanding of atmospheric phenomena and the processes which operate in the atmosphere and result in what is usually referred to as 'the weather'.

The first chapter entitled 'The drama of the weather' sets the scene and is followed by chapters covering the composition of the atmosphere, the radiation aspects and the gas laws, involving heat and temperature changes. Subsequent chapters discuss small-scale motions, large-scale motions and the general circulation, introducing topics usually covered by the term dynamic meteorology. Condensation and precipitation processes are then explained before dealing with the role of convection and the convective phenomena, thunderstorms and tornadoes.

A short chapter on air masses is followed by adequate chapters on fronts and cyclones and weather systems in the tropics.

Some space is devoted to weather forecasting and in this chapter as well as a description of some methods of weather prediction, the slightly controversial questions of predictability and accuracy of weather forecasts are also considered: examples are shown of forecasts produced by using modern electronic computers.

The final two chapters deal with air pollution and man's influence on the atmosphere, the concluding sections covering the effects of man's activities in the atmosphere — particularly in cities, and intentional weather modification experiments are discussed. Each chapter finishes with a list of questions designed to enable students to check on their understanding of the text.

This book started as a set of mimeographed notes, progressing to a preliminary edition which was then class-tested and critically examined by a large number of teaching professors in the U.S.A. This edition has undoubtedly been improved by the incorporation of suggestions arising from that exercise, and it now appears as a well-produced and well-illustrated book which fulfils in my opinion the hopes of the authors.

G. R. R. BENWELL

Principles of environmental physics, by J. L. Monteith. 215 mm × 135 mm, pp. xiv + 241, *illus.*, Edward Arnold Ltd, Woodlands Park, Maidenhead, Berkshire, 1973. Price: £6 (Paperback £3).

Progress in biology during the first half of the present century, although considerable, was to a certain extent handicapped by the absence of adequate inclusion of the relevant details from a sister-science, namely physics. Recognition of this defect has led to the institution of professorships at certain universities, and the Chair of Environmental Physics at the School of Agriculture, Sutton Bonington, University of Nottingham, is a case in point.

The occasion of the publication of a textbook in the Contemporary Biology series, by the present holder of that post, is therefore greatly to be welcomed. The author is under no illusion as to the difficulties of his task, as is shown by his pertinent quotation from Lucretius 'The main obstacles are the inadequacy of our language and the novelty of my subject'.

To overcome the language obstacle it is essential for the biologist to adopt the presentation techniques of the mathematician and mathematical physicist, no mean task when he probably abandoned the elements of both disciplines about the age of 16 in order to concentrate on a biological science. He must now prepare himself to be able to express his ideas and concepts in the form of equations, using a system of notation which may at first be foreign to him. To emphasize this the opening pages of this book contain a list of nearly 140 symbols used in the succeeding chapters — a new language indeed to someone whose previous training precluded such aids to scientific expression.

After outlining the scope of the volume, the author deals concisely and clearly with the basic physics of the gas and radiation laws. Radiation is then dealt with in greater detail, considering the analysis and interpretation of the radiation present in the environment and its modification within the domain of a plant, followed by a discussion of the all-important radiation balance. The next meteorological factor to be dealt with is wind, involving explanations of the momentum transfer in the boundary layers, the drag effect and the incidence of turbulence. This leads on to a treatment of the heat-exchange processes and the thermal balance including latent heat. Finally the book provides an introduction to the composite problems of the micrometeorology of crops, and a series of useful tables. A helpful bibliography of some 200 items is included but it is a pity that the World Meteorological Organization *Technical Note* No. 119 'The application of micro-meteorology to agricultural problems' was apparently published too late for inclusion.

Professor Monteith has dealt with a difficult and very complicated subject with admirable skill. The result is a book which the uninitiated may find difficult to digest without extensive mental effort, but the biological research student must master this approach to the solution of his problems if he is to reach real understanding of the sciences of the biosphere. The printing is of a high standard and the diagrams are excellently designed and reproduced.

L. P. SMITH

Britain's weather (its workings, lore and forcasting), by David Bowen. 220 mm × 145 mm, pp. 310, *illus.*, David and Charles (Holdings) Ltd, South Devon House, Newton Abbot, Devon, 1973. Price: £3·25.

This book is aimed very much at the meteorological layman, and attempts to cover in descriptive terms the various aspects of the weather which have an impact on man's activities. Early chapters on the basic techniques of meteorological observation are followed by sections on Weather Charts and Forecasts. Here the information is somewhat out-of-date, since very little emphasis is placed on the use of computers in the forecasting field.

General aspects of British Climate, Weather Lore and Weather Cycles are dealt with in a descriptive fashion and then in the chapter on 'Weather and Warfare', the author recounts the ways in which the weather has played a part in various military engagements from Crecy to D-Day. Mr Bowen presents two 'forecasts' which the Emperor Napoleon I would have found useful in the week leading up to Waterloo.

The section on 'Weather Control' begins with an account of 'fog sweeping', which leads into a description of the use of mesh screens at Gibraltar for the collection of water from cloud droplets. Here Mr Bowen's knowledge of the literature is shown to be less than adequate, since he attributes the initiative in this matter to E. A. J. Canessa, who first experimented there in 1968; no reference is made to G. W. Hurst's work at Gibraltar, results of which were published in 1959.

The book continues with a section on the effects of climate on man's physical (and mental) well-being and concludes with accounts of work performed by amateur meteorologists in recent years.

A general criticism of the book is that the author seems to relish recounting organizational detail when it is superfluous to his main theme, and the book would remain less obviously out-of-date if this detail were omitted. Examples of this are his stressing of the separate roles of the national and regional forecasts presented immediately before main BBC news bulletins, and his accounts of the Meteorological Office organizational structure.

To summarize, this book might be of interest to the meteorological novice, but its rather old-fashioned layout hardly makes it a bargain at £3·25 when there are other, cheaper, introductory texts on the market.

J. S. HOPKINS

The effect of thermometer screen design on the observed temperature, by W. R. Sparks. 270 mm × 210 mm, pp. 106, *illus.*, Secretariat of the World Meteorological Organization, Geneva, Switzerland, 1972.

The study and practice of meteorology on the world scale requires a uniform, or at least compatible, system of instrumental observations. The World Meteorological Organization (WMO) stresses this in its *Guide to meteorological instruments and observations*. Its technical notes and reports, written by specialists in particular problems, include advice and recommendations about such important matters as design, exposure and management, and assessments of desirable standards of accuracy. The present report is a valuable survey of the differing practices and the inconsistencies which still beset the apparently simple matter of measuring air temperature in the open.

Literature on thermometer screens goes back well over a hundred years. It was recognized at an early stage that to measure air temperature the thermometer must be screened from direct radiation. It was not always appreciated that the screen itself might then affect the reading. Mr Sparks discusses such effects, including the large thermal capacity of the screen which can have a very marked effect on the more transitory changes in temperature. Thus the smaller Bilham screen shows a higher maximum and a lower minimum than an adjacent similarly constructed but larger Stevenson screen. In this connection the accuracy of ± 0·5 degC in maximum and minimum temperatures set by WMO may need revising; so, too, may the 0·1-degC accuracy in 'synoptic' temperatures when an interval of 10 minutes is allowed. It is often supposed that provided different stations have identical screens at identical heights over identical ground, their temperatures will then be strictly comparable. However, a naturally ventilated screen is still affected by the local conditions of radiation and wind speed and direction.

The report is concerned only with 'dry-bulb' temperatures. The varying rate of air movement inside a naturally ventilated screen and the consequent effect on the 'wet-bulb' temperature can be an even more serious problem. Only an instrument with double radiation shields and adequate forced ventilation, properly designed for use in the open, avoids such errors. Not all Assman psychrometers are free from radiation and ventilation errors.

Mr Sparks describes numerous comparisons of various types of louvered screen. Several are of doubtful value, as the observations have not been taken at the same height, so the results do little more than confirm the existence of lapses and inversions. In this regard the WMO *Technical Regulation* permitting temperature observations between 1·25 and 2·00 m above the ground is not consistent with a required accuracy of 0·1 degC.

Under 'Novel screens' the writer describes various attempts to secure improved protection against radiation. Thus, some tropical countries erect a separate large roof of thatch or corrugated iron, the edges sometimes coming down to the level of the screen. It seems possible that air heated by contact with the roof may then enter the screen itself.

The author has had the difficult task of drawing conclusions from a mass of published information, from which even his abbreviated list extends to 90 references. He quite rightly draws attention to inconsistencies between officially recommended accuracy requirements for air temperature and the fact that we are measuring a fluctuating quantity and using an installation which has variable lag and susceptibility to radiation and wind. It is not obvious that comparisons against the CIMO-V Reference Psychrometer now being developed will lead to any better practical interpretation of screen readings. In reminding us again about the limitations of the every-day screen, Mr Sparks has made us think more carefully about what we are really trying to measure and how to do it. A cautionary tale.

Colleagues who need to use a bilingual dictionary may have difficulty with oversights in proof-reading such as Hydrometry (for Hygrometry), radio (ratio), ture (true), corregated (corrugated), and 'rigid (?) temperature fluctuations'.

S. G. CRAWFORD

Survey of instruments for micrometeorology (International Biological Programme Handbook No. 22*)*, compiled by J. L. Monteith. 210 mm × 150 mm, pp. xii + 263, *illus.*, Blackwell Scientific Publications, Osney Mead, Oxford OX2 0EL, 1972. Price: £3.

The material for this book has largely been obtained from questionnaires returned from 21 countries by manufacturers of instruments suitable for micrometeorological studies. A separate chapter is allocated to each of the following classes of instruments: thermometers and psychrometers, hygrometers and infra-red analysers, solarimeters and pyrheliometers, net radiometers, heat flow meters, anemometers, water content meters, water vapour flux meters, recorders and integrators. Each chapter has a brief introduction in which the merits and demerits of the various types of sensors are given.

A feature of this book is that the information on sensors is laid out in a standard format with one page for each instrument. This format includes space for a picture followed by itemized information such as type of instrument and name of the maker, specification, principle of operation, size, form and display of the output, sensitivity, etc. and an approximate price in 1971. A particularly interesting item is under the title 'users' in which names and addresses of institutions and people using an instrument are given thus enabling others to obtain first-hand knowledge about it. All the information given is as supplied by the manufacturers and naturally the editor is not responsible for its accuracy. Some of the instruments are different versions of the same device made by different makers in different countries. The chapters on recorders and integrators only include instruments which are suitable for field use and therefore independent of mains voltages. The book concludes with references to relevant publications for the period 1960–70.

The promoters of this book have done their part well but this cannot be said of all those supplying information, since many did not fully complete the questionnaires and in other cases the information had to be extracted from advertising literature. This results in blank spaces on many pages especially if the picture is lacking as it is in nearly half of the cases. This is an unusual book — possibly the first of its kind. Its layout makes for easy and quick reference and anyone working with this type of instrument will find the book extremely useful and time-saving. The editor hopes to bring out additional information either in the form of a supplement or as a new edition in which, it is to be hoped, the manufacturers will be more diligent in supplying information.

H. E. PAINTER

NOTES AND NEWS

The European Centre for Medium-range Weather Forecasts

On 11 October 1973 there was signed in Brussels the Convention establishing the European Centre for Medium-range Weather Forecasts. Fifteen countries signed, and others may do so later. The project for the Centre was developed over some three years as the biggest considered by the 19-nation COST group (European Co-operation in the field of Scientific and Technical Research). The Centre will have its permanent home in a new building to be erected at Shinfield Park, near Reading, after being housed meanwhile in Bracknell. Its main task is to develop computer methods of forecasting for periods of 4–10 days, to prepare such forecasts operationally, and to distribute them to the meteorological services of member States.

The Centre will be financed by the participating European States. It is expected to need an international staff of about 120 and a computer much larger in capacity than any so far employed in meteorology. A Council composed of representatives of the member States will govern the Centre through its Director. Because of the economic value foreseen for the Centre's products it has been recognized that no time should be lost, so until the Convention comes into force (depending on its ratification by States) an Interim Committee has been set up by the signatory States to get things moving. The Committee held its first meeting in Brussels on 26 October 1973.

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CONTENTS

NOTICES

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